Uncertain Supply Chain Management 11 (2023) 787–798

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

Exploring the effect of blockchain technology on supply chain resilience and transparency: Evidence from the healthcare industry

Zaid Alabaddi[a], Ahmad Obidat[a*] and Zaid Alziyadat[b]

[a]*Department of Management Information Systems, College of Business Administration and Economics, Al-Hussein Bin Talal University, Ma'an, Jordan*
[b]*Department of Business Administration, College of Business Administration and Economics, Al-Hussein Bin Talal University, Ma'an, Jordan*

A B S T R A C T

Article history:
Received October 6, 2022
Received in revised format October 18, 2022
Accepted December 29 2022
Available online January 1 2023

Keywords:
Supply chain resilience
Supply chain transparency
Smart contracts
Traceability
Data quality
Blockchain technology

Blockchain technology is revolutionizing all sectors of industries including the healthcare one. Blockchain technology applications have been realized in healthcare as they have the potential to revolutionize healthcare systems. Integrating blockchain into the design of supply chain design leads to decentralizing the management of the supply chain, and, in turn, improves workflow efficiency and reduces the various security threats. Therefore, this study aimed at examining the impact of integrating blockchain technology, into supply chain practices, on supply chain transparency and resilience. By adopting the organizational information processing theory, this study developed a research model that explored the impact of blockchain technology features including data quality, smart contracts, and traceability on supply chain resilience and transparency. Furthermore, this study examined the effect of supply chain transparency on supply chain resilience. The data was collected, from healthcare industry personnel, in Jordan, using an electronic survey. In total, 215 participants responded to the questionnaire. RStudio- 2022.07.1 was used to conduct the data analysis. Results revealed that data quality significantly and positively affects supply chain transparency and resilience. In addition to that, results indicated that while smart contracts are positively related to supply chain transparency, they do not affect supply chain resilience. Also, traceability was found to be positively related supply chain transparency and resilience. Finally, it was found that blockchain-driven supply chain transparency positively impacts blockchain-driven supply chain resilience. The results imply that integrating blockchain technology into the supply chain can enhance both supply chain transparency and resilience, and, in turn, provide the supply chain the capability of recovering to its original state should it encounter disruptive events. The outcomes of this study can help supply chain managers and other stakeholders to develop strategies and tactics to best utilize blockchain technology to enhance blockchain-driven supply chain transparency and resilience.

1. Introduction

The fast-paced development of Information and communications technology (ICT) has been revolutionizing the ways financial and non-financial transactions are conducted (Cordova-Buiza et al., 2022; Nofer et al., 2017). With each milestone achieved in ICT development, there are associated innovations in the ways how society trades and interacts (Büchi et al., 2019; Muna et al., 2022). With the emergence of Blockchain technology, a wider range of ICT tools has become available to empower stakeholders to innovate in response to pressure where other ICT tools might fall short in handling critical transaction-related issues, security, and privacy as examples (Al-Gasawneh et al., 2022; Axon et al., 2018; Wüst & Gervais, 2018).

* Corresponding author
E-mail address obidat.ahmad@gmail.com (A. Obidat)

doi: 10.5267/j.uscm.2023.1.001

Blockchain is a "decentralized data structure with internal consistency maintained through consensus reached by all the users on the current state of the network" (Dhillon et al., 2017, p. 15). It encompasses a range of ICT tools that enable information and digital assets exchange in distributed networks (Zahed Benisi et al., 2020). Blockchain technology gained its popularity when the Bitcoin cryptocurrency was introduced as the former was adopted as the technological framework for the latter (Monrat et al., 2019). Distinguishably, Blockchain allows encrypted peer-to-peer digital transactions without any need for a central authority. This resulted in an increased interest in Blockchain technology as it supports the decentralization of transactions, security, privacy, anonymity, public verifiability, and data integrity (Hamadneh et al., 2021; Wüst & Gervais, 2018).

Blockchain is considered a breakthrough technology (Alsmadi et al., 2022; Y. Chen, 2018). Blockchain technology has been used in a wide range of domains including financial and non-financial (Fahlevi et al., 2022; Nofer et al., 2017). In the financial industry, it's used in cryptocurrency applications, smart bonds or contracts, point of sales systems, lending and borrowing, stock markets, clearing and settlements, bookkeeping and auditing, hedge funds, credit score reports, etc. (Al-Zaqeba et al., 2022; Kurniasari et al., 2021; Laroiya et al., 2020). Also, Blockchain has been used in the Internet of Things (IoT), e-government, healthcare systems, education, agriculture, food industries, supply chain management, etc (Jaoude & Saade, 2019; Kurdi et al., 2022).

Blockchain technology applications have been realized in healthcare as they have the potential to revolutionize healthcare systems (Alzate et al., 2022; McGhin et al., 2019). Decentralizing healthcare information systems architecture eliminates the need for a third party for healthcare management. This enables the sharing of medical and patient-related information between health organizations in a way that protects the security and privacy of people (Hasselgren et al., 2020). Moreover, smart contracts can be integrated into Blockchain healthcare-based systems to allow for the verification and validation of medical and insurance records. As a result, any fraud, and counterfeiting transactions should be practically detected and prevented (Nguyen et al., 2020).

The supply chain is usually designed in a centralized fashion where all data and transactions are processed and managed at a single point (Awawdeh et al., 2022; Koilo, 2022; Zhu et al., 2020). This would make the supply chain subject to various fraud and counterfeiting threats. Such that unauthorized modifications to data records or various malicious attacks might take place within the supply chain management system (Ahmad, 2022; Yiu, 2021). Therefore, integrating Blockchain into the design of supply chain design leads to decentralizing the management of the supply chain, and, in turn, improves workflow efficiency and reduces the various security threats (ElRefae & Nuseir, 2021; Queiroz et al., 2020).

Owing to the importance of blockchain technology and its vital role in financial and non-financial sectors, a plethora of research has been done to explore blockchain technology applications in various fields (Guo et al., 2021). However, the applications of blockchain technology in the supply chain are relatively new (Dujak & Sajter, 2019). Therefore, there is a dearth of studies that examine the interplay between blockchain technology and supply chain applications and properties (Dutta et al., 2020). Thus, this study aims to examine the impact of integrating blockchain technology, into supply chain practices, on supply chain transparency and resilience.

2. Literature review

2.1. Theoretical framework

This study grounds itself in the Organizational Information Processing Theory (OIPT) (Galbraith, 1973). Blockchain technology is an ICT tool. Therefore, OIPT can provide a thorough understanding of the interplay between blockchain technology and the supply chain. According to OIPT, organizations should get the best of their information when accomplishing their various tasks, especially those that incur a high level of uncertainty. This requires that organizations should process and handle their information effectively and efficiently (Galbraith, 1974).

OIPT posits that organizations have two approaches to cope with their information needs, either they reduce their reliance on information by adopting mechanistic organizational approaches or maximize their information processing capabilities (Haußmann et al., 2012). Both approaches require that information should be shared within and between organizations. Therefore, it's argued that real-time, secure, and efficient information sharing and processing is vital in supporting various supply chain activities and practices (Zhaojing Wang et al., 2020).

Blockchain technology is considered a vital enabler in facilitating vertical and horizontal information sharing within and among organizations (Dutta et al., 2020). Therefore, integrating blockchain technology into the supply chain is expected to facilitate information sharing amongst supply chain partners. Consequently, proper alignment, through blockchain technology implementation, of the information processing needs and capabilities can enhance supply chain properties, transparency, and resilience. Furthermore, drawing on OIPT, supply chain transparency supports organizations' information processing capabilities, and, in turn, supply chain resilience (Dubey et al., 2020; Wong et al., 2020).

2.2. Data quality

Data quality, in Blockchain technology, encompasses multiple dimensions including distributed ledger (decentralization), immutability, and consensus mechanism (Elrefae & Nuseir, 2022). Distributed ledger technology is the main driver of Blockchain innovation (Benčić & Žarko, 2018). A distributed ledger is different from a centralized one in the way it stores and authenticates information. Whereas a central ledger stores information centrally, a distributed ledger stores them on a network of computers. To maintain the current status of the distributed ledger, all updates to data on computer nodes occur simultaneously. Meanwhile, before any update is reflected on the distributed ledger, the data or information is authenticated via a cryptographic protocol implemented between the network nodes, without a need for a third-party (Lashkari & Musilek, 2021). Immutability is inherited from the decentralized nature of Blockchain (Dwivedi et al., 2020). The immutability feature has the potential to protect blockchain users from various illegal threats and activities (Gonczol et al., 2020). The consensus mechanism enables the verification of transactions by obtaining an agreement from all nodes in the Blockchain network (Lashkari & Musilek, 2021).

Previous research found that data quality is one of the main drivers of blockchain technology adoption (Dehghani et al., 2022). Also, previous studies found that while data immutability, as one of the main characteristics of blockchain technology, positively relates to supply chain partnership growth, it does not affect supply chain partnership efficiency (Kim & Shin, 2019). Thus, the following two hypotheses are made:

Hypothesis 1 (H1): *Data quality positively relates to supply chain transparency.*

Hypothesis 2 (H2): *Data quality positively relates to supply chain resilience.*

2.3. Smart contracts

Smart contracts are considered a major application provided by Blockchain technology (Liu et al., 2022). Smart contracts are defined as "computer protocols that digitally facilitate, verify, and enforce the contracts made between two or more parties on Blockchain" (Wang et al., 2019, p. 2266). They enable a decentralized automated execution and enforcement of the contractual terms between the involved parties (Lin et al., 2022). Ethereum and Hyperledger Fabric Blockchain-based smart contracts are the most popular forms of smart contracts (Androulaki et al., 2018; Zeli Wang et al., 2020). The combination of Blockchain and smart contracts expanded the spectrum of Blockchain applications into many fields including healthcare, IoT, financial services, supply chain management, etc. (Christidis & Devetsikiotis, 2016; Lutfi et al., 2020).

Previous studies found that smart contracts have a positive effect on partners' trust in the supply chain and on the visibility of the supply chain (P.-K. Chen et al., 2022). Moreover, previous research indicated that while smart contracts positively relate to supply chain partnership efficiency they do not affect supply chain partnership growth (Kim & Shin, 2019). Thus, the following two hypotheses are made:

Hypothesis 3 (H3): *Smart contracts positively relate to supply chain transparency*.

Hypothesis 4 (H4): *Smart contracts positively relate to supply chain resilience*.

2.4. Traceability

Data provenance is essential for business practices including ethical issues as far as tracking the origin of supplies and goods, the calculation of environmental footprints of products and their components throughout their life cycle, and providing ongoing support and monitoring for business processes and workflow (Ametepe et al., 2021). Therefore, for a supply chain management system to achieve traceability and transparency, there is a need to integrate it with a technology that enables such functionalities. Blockchain technology is well known for providing traceability and transparency for various types of transactions due to its distinguishing characteristic of relying on an immutable ledger (Raja Santhi & Muthuswamy, 2022). So, a Blockchain-based supply chain management system should provide organizations and individuals the ability to authenticate and trace provenance records transparently (Mann et al., 2018; Perkumiene et al., 2021). Moreover, traceability and transparency of provenance records are expected to count to the threat of counterfeiting (Uddin, 2021). This can be achieved by eliminating the need for a centralized authority, and so reducing the likelihood of meddling with stored data records on the distributed network (Musamih et al., 2021).

Supply chain management involves moving products and entities across different locations or points until they reach their destination (Koilo, 2021; Laroiya et al., 2020). This process entails serious problems including susceptibility to security and privacy breaches and improper authentication among the participants in the supply chain (Alarefi, 2023; Chhetri et al., 2018; Shamsi et al., 2019). The decentralization, transparency, anonymity, and immutability characteristics of Blockchain make it a potential candidate to achieve a better supply chain management system (Rejeb et al., 2019). Through cryptographic keys, the technical mechanism employed by Blockchain technology, information can be shared securely and privately, among users, in the supply chain system (Arun Kumar, 2022). Cryptographic keys are used to authenticate the exchange of data and other uses of information with smart contracts and a consensus mechanism, while the senders and receivers remain anonymous (De Giovanni, 2020). Traceability is a critical factor for supply chain management systems (Alhalalmeh, 2022; Centobelli et al., 2021). Users of a supply chain need to store traceable records of data to maintain robustness in handling critical information (Fan et al., 2022). Blockchain technology is characterized by its ability to support the traceability of information. Therefore, research began to examine the feasibility and requirements of designing Blockchain-based supply chain management systems in various industries (Dasaklis et al., 2022; Song et al., 2019). Traceability in supply chain management systems helps prevent fraudulent and counterfeit activities (Collart & Canales, 2022; Cousins et al., 2019; Salah et al., 2019). Moreover, traceability can support supply chain transparency (Sunny et al., 2020).

Previous studies demonstrated that traceability positively relates to trust in Blockchain technology (Wallbach et al., 2020). Also, research revealed that traceability is a major predictor of adopting Blockchain technology in the supply chain (Anastasiadis et al., 2022). Moreover, a previous study conducted by Montecchi et al. (2021) revealed that traceability is a key driver of supply chain transparency. Therefore, this study proposes the following two hypotheses:

Hypothesis 5 (H5): *Traceability positively relates to supply chain transparency*.

Hypothesis 6 (H6): *Traceability positively relates to supply chain resilience*.

2.5. Supply chain resilience

Supply chain resilience is defined as "the adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations ideally, a better state than before the disruption" (Tukamuhabwa et al., 2015, p. 5599). Supply chain resilience is a necessity to react to outbreaks and disruptions (Ivanov & Dolgui, 2020). Supply chain resilience helps improve risk and crisis management performance for firms (Belhadi et al., 2022; Wong et al., 2020). Moreover, supply chain resilience can enhance organizational resilience (Parast, 2022) and supply chain sustainability (Khot & Thiagarajan, 2019). Research demonstrated that knowledge management (Jüttner & Maklan, 2011) and the intellectual capital of a firm (Mubarik et al., 2022) positively relate to supply chain resilience. In general, technological innovation can indeed enhance the resilience of the supply chain (Ozdemir et al., 2022). Industry 4.0 ICT tools have the potential to improve supply chain resilience (Saha et al., 2022; Spieske & Birkel, 2021). For example, big data analytics can improve supply chain resilience (Gupta et al., 2022). Also, blockchain can enhance supply chain resilience by improving security and visibility (Pettit et al., 2019).

2.6. Supply chain transparency

Supply chain transparency is "the extent to which information is readily available to end-users and other firms in the supply chain" (Awaysheh & Klassen, 2010, p. 1249). Supply chain transparency offers several benefits to companies including managing supply chain risks, reducing reputational damages, improving supply chain efficiency, gaining consumers' and investors' trust, meeting regulatory compliance or preventing bad publicity, and monitoring suppliers through crowdsourcing (Sodhi & Tang, 2019). The research found that blockchain, through wider information sharing, can enhance the transparency of the supply chain (Bai & Sarkis, 2020). Also, previous studies found that supply chain adaptability and flexibility can improve supply chain resilience (Hobbs, 2021). Moreover, previous research found that supply chain transparency increases supply chain sustainability and resilience (Gardner et al., 2019; Montecchi et al., 2021). Therefore, this study proposes the following hypothesis:

Hypothesis 7 (H7): *Blockchain-driven supply chain transparency positively impacts blockchain-driven supply chain resilience*.

Fig. 1, below, captures the research model that was developed based on the literature review.

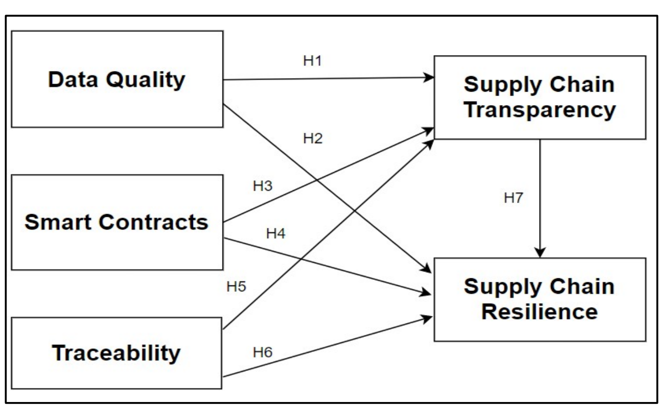

Fig. 1. Research model

3. Methodology

3.1. Data collection

The data for this research study was collected through a web-based survey. The survey included two sections. The first part of the survey sought demographic data about participants, and the second part sought an assessment of the items comprising the research model's constructs. In the beginning, potential participants, who work in the healthcare industry in Jordan, were approached by email, and they were asked to forward the invitation to fill out the survey to people who fit the target description of participants for this study. That is, in the invitation email, it was explained that the survey targets participants who work in the pharmaceutical and medical supplies manufacturing sector, and in companies that implement blockchain technology in their supply chain operations. The first page of the questionnaire explained the aim of the study and indicated that participation is voluntary. An invitee was asked to only complete the survey if he/she fits the description of a participant. All participants consented before completing the survey. Two hundred and fifteen people participated in the survey.

3.2. Measuring instrument

All constructs in this research study were operationalized using previously validated measurement items, in the literature. Traceability was measured by three items adapted from (Esfahbodi et al., 2022; Saurabh & Dey, 2021). The three items measuring the smart contracts construct were obtained from (Badi et al., 2021). Data quality was operationalized using four items adopted from (Dehghani et al., 2022). Supply chain resilience was assessed by four items based on (El-Baz & Ruel, 2021). Supply chain transparency was evaluated by four items based on (Kashmanian, 2017; Zelbst et al., 2020).

4. Results

4.1. Demographic characteristics of the study's sample

Two hundred and fifteen participants responded to the online survey. Table 1 captures the study's sample characteristics.

Table 1
Sample demographics

Respondents Profile	Classification	Frequency	(%)	Classification	Frequency	(%)	Classification
Gender	Male	122	57%	**Industry classification**	Pharmaceutical factories	127	59%
	Female	93	43%		Medical supplies	88	41%
	Total	215	100%		Total	215	100%
Age	20–24 years	66	30.7%				
	25–29 years	68	31.6%				
	30–34 years	30	14%				
	35–40 years	33	15.3%				
	Above 40 years	18	8.4 %				
	Total	215	100%				

4.2. Convergent validity

As recommended by Hair (2009), to assess the convergent validity, of the model, four criteria were examined including (1) the standardized Factor Loading (FL), which must be above 0.5, for each survey item measuring a variable, (2) Cronbach's alpha (**α**), which must be above 0.8, for all variables, (3) Composite Reliability (CR), which must be above 0.8, for all variables, and (4) the Average Variance Extracted (AVE), which must be above 0.5, for all variables. Table 2 captures the assessment results of the convergent validity. Based on that, it can be inferred that the convergent validity of the model is met.

Table 2
Convergent validity evaluation

Variable	FL	α	CR	AVE
Traceability		0.85	0.86	0.67
1. Blockchain technology enables our organization to track the logistics accurately	0.69			
2. Blockchain technology enables our organization to track the logistics reliably	0.89			
3. Blockchain technology enables real-time tracking and tracing of product/service movement	0.86			
Smart contract		0.86	0.86	0.67
1. A smart contract provides secured and fast payments	0.82			
2. A smart contract reduces the occurrence of disputes between our organization and our contracting	0.83			
3. A smart contract increases trust between our organization and our contracting parties	0.80			
Data quality		0.94	0.94	0.80
1. Blockchain technology reduces the risk of a single point of failure	0.87			
2. Blockchain technology provides a tamper-evident data structure	0.89			
3. Blockchain technology increases the efficiency in performing data reconciliation	0.91			
4. Blockchain technology supports data auditability	0.90			
Supply chain resilience		0.89	0.89	0.68
1. Our organization can cope with changes brought by the supply chain disruption	0.81			
2. Our organization can adapt to supply chain disruption easily	0.79			
3. Our organization can provide a quick response to the supply chain disruption	0.83			
4. Our organization can maintain high situational awareness at all times	0.85			

Table 2
Convergent validity evaluation (Continued)

Variable	FL	α	CR	AVE
Supply chain transparency		0.95	0.95	0.84
1. Our organization has mapped its supply chain and provided the mapping information to our supply chain partners and customers	0.92			
2. Material flows from our suppliers have been mapped and related information is available for our supply chain partners and customers to view	0.93			
3. Our organization provides our supply chain partners and customers with information that allows them to easily determine the specific materials used to make our products and where those materials are produced.	0.88			
4. Our organization provides its supply chain partners and customers with information that proves that the materials used to produce our products are responsibly and sustainably sourced or produced.	0.92			

4.3 Discriminant validity

The Heterotrait–Monotrait (HTMT) ratio of correlations criterion was adopted to evaluate the discriminant validity of the model. This criterion postulates that the correlation among constructs composing the model should be less than 0.85 (Franke & Sarstedt, 2019). Table 3 captures the HTMT evaluation. Based on that it can be concluded that the discriminant validity is met.

Table 3
HTMT results

Construct	Supply chain resilience	Supply chain transparency	Traceability	Data quality	Smart contract
Supply chain resilience	1.000				
Supply chain transparency	0.773	1.000			
Traceability	0.831	0.729	1.000		
Data quality	0.772	0.779	0.649	1.000	
Smart contract	0.667	0.717	0.681	0.724	1.000

4.4. Structural model goodness-of-fit

The goodness of fit was examined against five indices. Table 4 captures the fit indices and their associated values in the tested structural model, cut-off values, and sources. According to these results, the structural model meets the goodness-of-fit criteria.

Table 4
Fit indices for the tested structural model

Fit index	Model Value	Cut-off value	Source
Relative Non-Centrality Index	0.962	> 0.9	(Bentler & Bonett, 1980)
Tucker-Lewis Index	0.954	> 0.95	(Hooper et al., 2008)
Comparative Fit Index	0.962	> 0.95	(Hooper et al., 2008)
Root Mean Square Error of Approximation	0.072	< .08	(Browne & Cudeck, 1992)
Standardized Root Mean Square Residual	0.035	< .08	(Hu & Bentler, 1999)

4.5. Hypothesis testing results

Table 5 captures the hypothesis testing results. Also, a pictorial representation of the hypothesis testing results is captured in Fig. 2.

Table 5
Hypotheses testing results

Path	Standardized coefficient	z-value	P(>|z|)	Decision
H1: DQ → SCT	0.506	5.868	0.000 ****	Supported
H2: DQ → SCR	0.306	4.037	0.000 ****	Supported
H3: SC→ SCT	0.243	2.497	0.013 *	Supported
H4: SC → SCR	-0.021	-0.270	0.787	Not Supported
H5: TR → SCT	0.401	4.057	0.000 ****	Supported
H6: TR → SCR	0.570	6.066	0.000 ****	Supported
H7: SCT → SCR	0.145	2.161	0.031 *	Supported

Note. Significance codes: 0.000 **** 0.001 *** 0.01** 0.05*. DQ: Data Quality, SCT: Supply Chain Transparency, SCR: Supply Chain Resilience, SC: Smart Contracts, TR: Traceability.

The hypothesis testing results revealed that data quality (z=5.868, p=0.000) is statistically significantly related to supply chain transparency. Also, data quality (z=4.037, p=0.000) is statistically significantly related to supply chain resilience. Besides that, findings showed that while smart contracts (z=2.497, p=0.013) are statistically significantly related to supply chain transparency, they do not affect supply chain resilience. Moreover, the results of the study found that traceability (z=4.057, p=0.000) is statistically significantly related to supply chain transparency. Also, traceability (z=6.066, p=0.000) was found to be statistically significantly related to supply chain resilience. Finally, it was found that blockchain-driven supply chain transparency (z=2.161, p=0.031) has a statistically significant positive direct effect on blockchain-driven supply chain resilience.

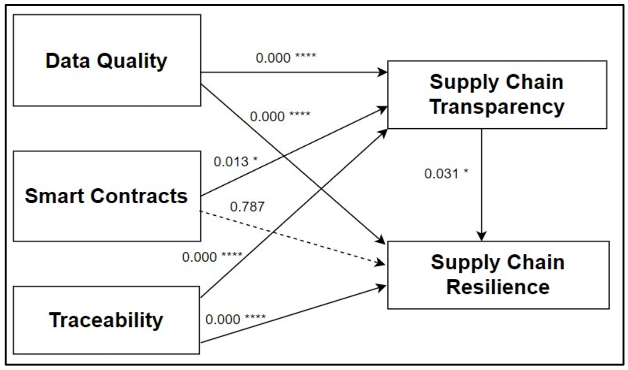

Fig. 2. Hypothesis testing results

5. Discussion

The purpose of this study was to examine the impact of integrating blockchain technology, into supply chain practices, on supply chain transparency and resilience. Furthermore, this study explored the effects of supply chain transparency on supply chain resilience.

Data quality was found to be positively related to supply chain transparency and resilience. Therefore, H1 and H2 are supported. This finding is in support of a previous study that found that data quality is one of the main drivers of blockchain technology adoption (Dehghani et al., 2022). Also, this outcome is in line with a previous study that found that data immutability positively relates to supply chain partnership growth (Kim & Shin, 2019). Therefore, it might be inferred that data quality is a major enabler of supply chain transparency and resilience as it is one of the main predictors of blockchain technology adoption and supply chain partnership growth.

Also, the results of this study revealed that while smart contracts are positively related to supply chain transparency, they do not affect supply chain resilience. Thus, H3 is supported while H4 is not. The found relationship between smart contracts and supply chain transparency is in support of previous studies which found that smart contracts have a positive effect on partners' trust in the supply chain and on the visibility of the supply chain (Chen et al., 2022), and on supply chain partnership efficiency (Kim & Shin, 2019). Therefore, it might be inferred that smart contracts are a major enabler of partners' trust in the supply chain and supply chain visibility and partnership efficiency.

Moreover, the results of the study found that traceability positively impacts supply chain transparency and resilience. Thus, H5 and H6 are supported. This finding corroborates the outcomes of previous studies that found that traceability positively relates to trust in blockchain technology (Wallbach et al., 2020), as it is one of the major predictors of adopting blockchain technology in the supply chain (Anastasiadis et al., 2022). Moreover, this outcome supports the finding of a previous study that found that traceability is a key enabler of supply chain transparency (Montecchi et al., 2021). Therefore, it might be inferred that traceability is one of the major predictors of trust in, and adoption of, blockchain technology as well as a critical enabler of supply chain transparency and resilience.

Finally, it was found that blockchain-driven supply chain transparency positively relates to blockchain-driven supply chain resilience. Thus, H7 is supported. This finding corroborates the outcomes of previous studies that found that supply chain adaptability and flexibility can improve supply chain resilience (Hobbs, 2021). Also, this finding is in line with previous research that found that supply chain transparency increases supply chain sustainability and resilience (Gardner et al., 2019; Montecchi et al., 2021). Therefore, it might be inferred that blockchain-driven supply chain transparency, adaptability, and flexibility can enhance blockchain-driven supply chain resilience.

6. Conclusion

This study aimed at examining the impact of integrating blockchain technology, into supply chain practices, on supply chain transparency and resilience. Therefore, this study explored the impact of blockchain technology features including data quality, smart contracts, and traceability on supply chain resilience and transparency. Furthermore, this study examined the effect of supply chain transparency on supply chain resilience. The findings show that data quality is statistically significantly related to supply chain transparency and resilience. Besides that, findings indicated that while smart contracts are positively related to supply chain transparency, they do not affect supply chain resilience. Also, traceability was found to be statistically significantly related to supply chain transparency and resilience. Finally, it was found that blockchain-driven supply chain transparency is statistically significantly related to blockchain-driven supply chain resilience.

6.1. Practical implications

Data quality, as a quality feature of blockchain technology, was found to be positively related to supply chain transparency and resilience. This implies that data quality is an important enabler of supply chain transparency and resilience. Thus, organizations should allocate resources for possible blockchain applications. Also, they should realize the importance and advantages of data quality features provided by blockchain technology including distributed ledger (decentralization), immutability, and consensus mechanisms. Smart contracts were found to be positively related to supply chain transparency and resilience. This implies that smart contracts are a vital enabler of supply chain transparency and resilience. Therefore, organizations should rely on smart contracts for automatic verification and execution of agreements by examining the conditions of contracts. Traceability was found to be positively related to supply chain transparency and resilience. This implies that traceability is a critical enabler of supply chain transparency and resilience. Therefore, organizations should endeavor to implement blockchain technology as it enables the process of verifying the origin of products and information about the track that products go through from their place of origin to their destination.

Finally, it was found that blockchain-driven supply chain transparency positively impacts blockchain-driven supply chain resilience. This implies that blockchain-driven supply chain transparency is a vital enabler of blockchain-driven supply chain resilience. Therefore, organizations should endeavor to achieve long-term information exchange with an organization and with other business partners. Moreover, organizations should develop appropriate tactics to increase the visibility of their supply chains.

6.2. Research implications

This research study contributes, significantly, to the literature on the impact of integrating blockchain technology into supply chain practices, on supply chain transparency and resilience, and the relationship between supply chain transparency and resilience. The theoretical implications of this study indicate that data quality positively impacts supply chain transparency and resilience. In addition to that, while smart contracts positively affect supply chain transparency, they do not affect supply chain resilience. Moreover, it was found that traceability positively affects supply chain transparency and resilience. Finally, it was found that blockchain-driven supply chain transparency is positively related to blockchain-driven supply chain resilience.

6.3. Limitations

While a significant contribution has been made by this study to the literature, it only examined two properties of the supply chain, transparency, and resilience. Also, this study was limited to one industrial sector, healthcare. Therefore, it is recommended that future studies should examine the impact of integrating blockchain on other supply chain properties, and in different industrial sectors.

References

Ahmad, H. (2022). Factors affecting supply chain integration and customer satisfaction. *Uncertain Supply Chain Management, 10*(3), 1037-1040. http://dx.doi.org/10.5267/j.uscm.2022.2.008

Al-Gasawneh, J., AL-Hawamleh, A., Alorfi, A., & Al-Rawashde, G. (2022). Moderating the role of the perceived security and endorsement on the relationship between per-ceived risk and intention to use the artificial intelligence in financial services. *International Journal of Data and Network Science, 6*(3), 743-752. http://dx.doi.org/10.5267/j.ijdns.2022.3.007

Al-Zaqeba, M., Jarah, B., Ineizeh, N., Almatarneh, Z., & Jarrah, M. (2022). The effect of management accounting and blockchain technology characteristics on supply chains efficiency. *Uncertain Supply Chain Management, 10*(3), 973-982. http://dx.doi.org/10.5267/j.uscm.2022.2.016

Alarefi, M. (2023). Adoption of IoT by telecommunication companies in GCC: The role of blockchain. *Decision Science Letters, 12*(1), 55-68. http://dx.doi.org/10.5267/j.dsl.2022.10.006

Alhalalmeh, M. (2022). The impact of supply chain 4.0 technologies on its strategic outcomes. *Uncertain Supply Chain Management, 10*(4), 1203-1210. http://dx.doi.org/10.5267/j.uscm.2022.8.008

Alsmadi, A., Alrawashdeh, N., Al-Dweik, A., & Al-Assaf, M. (2022). Cryptocurrencies: A bibliometric analysis. *International Journal of Data and Network Science, 6*(3), 619-628. http://dx.doi.org/10.5267/j.ijdns.2022.4.011

Alzate, I., Manotas, E., Boada, A., & Burbano, C. (2022). Meta-analysis of organizational and supply chain dynamic capabilities: A theoretical-conceptual relationship. *Problems and Perspectives in Management, 20*(3), 335-349. http://dx.doi.org/10.21511/ppm.20(3).2022.27

Ametepe, W., Wang, C., Ocansey, S. K., Li, X., & Hussain, F. (2021). Data provenance collection and security in a distributed environment: a survey. *International Journal of Computers and Applications, 43*(1), 11-25. https://doi.org/10.1080/1206212X.2018.1501937

Anastasiadis, F., Manikas, I., Apostolidou, I., & Wahbeh, S. (2022). The role of traceability in end-to-end circular agri-food supply chains. *Industrial Marketing Management, 104*, 196-211. https://doi.org/10.1016/j.indmarman.2022.04.021

Androulaki, E., Barger, A., Bortnikov, V., Cachin, C., Christidis, K., Caro, A. D., . . . Yellick, J. (2018). *Hyperledger fabric: a distributed operating system for permissioned blockchains*. Paper presented at the Proceedings of the Thirteenth EuroSys Conference, Porto, Portugal. https://doi.org/10.1145/3190508.319053810.1145/3190508.3190538

Arun Kumar, B. R. (2022). *Developing Business-Business Private Block-Chain Smart Contracts Using Hyper-Ledger Fabric for Security, Privacy and Transparency in Supply Chain.* Paper presented at the Data Management, Analytics and Innovation, Singapore. https://doi.org/10.1007/978-981-16-2937-2_26

Awawdeh, H., Abulaila, H., Alshanty, A., & Alzoubi, A. (2022). Digital entrepreneurship and its impact on digital supply chains: The mediating role of business intelligence applications. *International Journal of Data and Network Science, 6*(1), 233-242. http://dx.doi.org/10.5267/j.ijdns.2021.9.005

Awaysheh, A., & Klassen, R. D. (2010). The impact of supply chain structure on the use of supplier socially responsible practices. *International Journal of Operations & Production Management, 30*(12), 1246-1268. https://doi.org/10.1108/01443571011094253

Axon, L., Goldsmith, M., & Creese, S. (2018). Privacy Requirements in Cybersecurity Applications of Blockchain. In P. Raj & G. C. Deka (Eds.), *Advances in Computers* (Vol. 111, pp. 229-278). Elsevier.https://doi.org/10.1016/bs.adcom.2018.03.004

Badi, S., Ochieng, E., Nasaj, M., & Papadaki, M. (2021). Technological, organisational and environmental determinants of smart contracts adoption: UK construction sector viewpoint. *Construction Management and Economics, 39*(1), 36-54. https://doi.org/10.1080/01446193.2020.1819549

Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research, 58*(7), 2142-2162. https://doi.org/10.1080/00207543.2019.1708989

Belhadi, A., Kamble, S. S., Venkatesh, M., Chiappetta Jabbour, C. J., & Benkhati, I. (2022). Building supply chain resilience and efficiency through additive manufacturing: An ambidextrous perspective on the dynamic capability view. *International Journal of Production Economics, 249*, 108516. https://doi.org/10.1016/j.ijpe.2022.108516

Benčić, F. M., & Žarko, I. P. (2018). *Distributed Ledger Technology: Blockchain Compared to Directed Acyclic Graph.* Paper presented at the 2018 IEEE 38th International Conference on Distributed Computing Systems (ICDCS). https://doi.org/10.1109/ICDCS.2018.00171

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88*, 588-606. https://psycnet.apa.org/doi/10.1037/0033-2909.88.3.588

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research, 21*(2), 230-258. https://doi.org/10.1177/0049124192021002005

Büchi, M., Festic, N., & Latzer, M. (2019). Digital overuse and subjective well-being in a digitized society. *Social Media+ Society, 5*(4), 1-12. https://doi.org/10.1177%2F2056305119886031

Centobelli, P., Cerchione, R., Vecchio, P. D., Oropallo, E., & Secundo, G. (2021). Blockchain technology for bridging trust, traceability and transparency in circular supply chain. *Information & Management*, 103508. https://doi.org/10.1016/j.im.2021.103508

Chen, P.-K., He, Q.-R., & Chu, S. (2022). Influence of blockchain and smart contracts on partners' trust, visibility, competitiveness, and environmental performance in manufacturing supply chains. *Journal of Business Economics and Management, 23*(4), 754–772. https://doi.org/10.3846/jbem.2022.16431

Chen, Y. (2018). Blockchain tokens and the potential democratization of entrepreneurship and innovation. *Business Horizons, 61*(4), 567-575. https://doi.org/10.1016/j.bushor.2018.03.006

Chhetri, S. R., Faezi, S., Rashid, N., & Al Faruque, M. A. (2018). Manufacturing supply chain and product lifecycle security in the era of Industry 4.0. *Journal of Hardware and Systems Security, 2*(1), 51-68. https://doi.org/10.1007/s41635-017-0031-0

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the internet of things. *IEEE Access, 4*, 2292-2303. https://doi.org/10.1109/ACCESS.2016.2566339

Collart, A. J., & Canales, E. (2022). How might broad adoption of blockchain-based traceability impact the U.S. fresh produce supply chain? *Applied Economic Perspectives and Policy, 44*(1), 219-236. https://doi.org/10.1002/aepp.13134

Cordova-Buiza, F., Aguirre-Parra, P., Garcia-Jimenez, M. G., & Martinez-Torres, D. C. (2022). Virtual leadership as a development opportunity in business context. *Problems and Perspectives in Management, 20*(2), 248-259. http://dx.doi.org/10.21511/ppm.20(2).2022.20

Cousins, P. D., Lawson, B., Petersen, K. J., & Fugate, B. (2019). Investigating green supply chain management practices and performance. *International Journal of Operations & Production Management, 39*(5), 767-786. https://doi.org/10.1108/IJOPM-11-2018-0676

Dasaklis, T. K., Voutsinas, T. G., Tsoulfas, G. T., & Casino, F. (2022). A systematic literature review of blockchain-enabled supply chain traceability implementations. *Sustainability, 14*(4), 2439. https://doi.org/10.3390/su14042439

De Giovanni, P. (2020). Blockchain and smart contracts in supply chain management: A game theoretic model. *International Journal of Production Economics, 228*, 107855. https://doi.org/10.1016/j.ijpe.2020.107855

Dehghani, M., William Kennedy, R., Mashatan, A., Rese, A., & Karavidas, D. (2022). High interest, low adoption. A mixed-method investigation into the factors influencing organisational adoption of blockchain technology. *Journal of Business Research, 149*, 393-411. https://doi.org/10.1016/j.jbusres.2022.05.015

Dhillon, V., Metcalf, D., & Hooper, M. (2017). Foundations of Blockchain. In V. Dhillon, D. Metcalf, & M. Hooper (Eds.), *Blockchain Enabled Applications* (pp. 15-24): Apress.https://doi.org/10.1007/978-1-4842-3081-7_3

Dubey, R., Gunasekaran, A., Bryde, D. J., Dwivedi, Y. K., & Papadopoulos, T. (2020). Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting. *International Journal of Production Research, 58*(11), 3381-3398. https://doi.org/10.1080/00207543.2020.1722860

Dujak, D., & Sajter, D. (2019). Blockchain applications in supply chain. In A. Kawa & A. Maryniak (Eds.), *SMART Supply Network* (pp. 21-46). Cham: Springer International Publishing.https://doi.org/10.1007/978-3-319-91668-2_2

Dutta, P., Choi, T.-M., Somani, S., & Butala, R. (2020). Blockchain technology in supply chain operations: Applications, challenges and research opportunities. *Transportation Research Part E: Logistics and Transportation Review, 142*, 102067. https://doi.org/10.1016/j.tre.2020.102067

Dwivedi, S. K., Amin, R., & Vollala, S. (2020). Blockchain based secured information sharing protocol in supply chain management system with key distribution mechanism. *Journal of Information Security and Applications, 54*, 102554. https://doi.org/10.1016/j.jisa.2020.102554

El-Baz, J., & Ruel, S. (2021). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. *International Journal of Production Economics, 233*, 107972. https://doi.org/10.1016/j.ijpe.2020.107972

ElRefae, G., & Nuseir, M. (2021). The relationship among digital business strategy, knowledge sharing and supply chain: Exploring mediating effect of blockchain adoption. *Uncertain Supply Chain Management, 9*(4), 1027-1036. http://dx.doi.org/10.5267/j.uscm.2021.x.002

Elrefae, G., & Nuseir, M. (2022). Blockchain in global finance make-over: Exploring the mediating role of supply chain flexibility. *Uncertain Supply Chain Management, 10*(3), 983-992. http://dx.doi.org/10.5267/j.uscm.2022.2.015

Esfahbodi, A., Pang, G., & Peng, L. (2022). Determinants of consumers' adoption intention for blockchain technology in E-commerce. *Journal of Digital Economy, 1*(2), 89-101. https://doi.org/10.1016/j.jdec.2022.11.001

Fahlevi, M., Vional, V., & Pramesti, R. (2022). Blockchain technology in corporate governance and future potential solution for agency problems in Indonesia. *International Journal of Data and Network Science, 6*(3), 721-726. http://dx.doi.org/10.5267/j.ijdns.2022.3.010

Fan, Z.-P., Wu, X.-Y., & Cao, B.-B. (2022). Considering the traceability awareness of consumers: should the supply chain adopt the blockchain technology? *Annals of Operations Research, 309*(2), 837-860. https://doi.org/10.1007/s10479-020-03729-y

Franke, G., & Sarstedt, M. (2019). Heuristics versus statistics in discriminant validity testing: a comparison of four procedures. *Internet Research, 29*(3), 430-447. https://doi.org/10.1108/IntR-12-2017-0515

Galbraith, J. (1973). *Designing complex organizations*. Boston: Addison-Wesley Longman Publishing.

Galbraith, J. R. (1974). Organization design: An information processing view. *Interfaces, 4*(3), 28-36. https://doi.org/10.1287/inte.4.3.28

Gardner, T. A., Benzie, M., Börner, J., Dawkins, E., Fick, S., Garrett, R., . . . Wolvekamp, P. (2019). Transparency and sustainability in global commodity supply chains. *World Development, 121*, 163-177. https://doi.org/10.1016/j.worlddev.2018.05.025

Gonczol, P., Katsikouli, P., Herskind, L., & Dragoni, N. (2020). Blockchain implementations and use cases for supply chains-A survey. *IEEE Access, 8*, 11856-11871. https://doi.org/10.1109/ACCESS.2020.2964880

Guo, Y.-M., Huang, Z.-L., Guo, J., Guo, X.-R., Li, H., Liu, M.-Y., . . . Nkeli, M. J. (2021). A bibliometric analysis and visualization of blockchain. *Future Generation Computer Systems, 116*, 316-332. https://doi.org/10.1016/j.future.2020.10.023

Gupta, S., Bag, S., Modgil, S., Beatriz Lopes de Sousa Jabbour, A., & Kumar, A. (2022). Examining the influence of big data analytics and additive manufacturing on supply chain risk control and resilience: An empirical study. *Comput Ind Eng, 172*, 108629. https://doi.org/10.1016/j.cie.2022.108629

Hair, J. (2009). *Multivariate data analysis: A global perspective* (7th ed ed.). Saddle River: Prentice Hall.

Hamadneh, S., Keskin, E., Alshurideh, M., Al-Masri, Y., & Kurdi, B. (2021). The benefits and challenges of RFID technology implementation in supply chain: A case study from the Turkish construction sector. *Uncertain Supply Chain Management, 9*(4), 1071-1080. http://dx.doi.org/10.5267/j.uscm.2021.x.006

Hasselgren, A., Kralevska, K., Gligoroski, D., Pedersen, S. A., & Faxvaag, A. (2020). Blockchain in healthcare and health sciences—A scoping review. *International Journal of Medical Informatics, 134*, 104040. https://doi.org/10.1016/j.ijmedinf.2019.104040

Haußmann, C., Dwivedi, Y. K., Venkitachalam, K., & Williams, M. D. (2012). A summary and review of Galbraith's organizational information processing theory. In Y. K. Dwivedi, M. R. Wade, & S. L. Schneberger (Eds.), *Information systems theory: Explaining and predicting our digital society* (pp. 71-93). New York, NY: Springer New York.https://doi.org/10.1007/978-1-4419-9707-4_5

Hobbs, J. E. (2021). Food supply chain resilience and the COVID-19 pandemic: What have we learned? *Canadian Journal of Agricultural Economics, 69*(2), 189–196. https://doi.org/10.1111/cjag.12279

Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural equation modelling: Guidelines for determining model fit. *Electronic journal of business research methods, 6*(1), 53-60.

Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. *International Journal of Production Research, 58*(10), 2904-2915. https://doi.org/10.1080/00207543.2020.1750727

Jaoude, J. A., & Saade, R. G. (2019). Blockchain applications – Usage in different domains. *IEEE Access, 7*, 45360-45381. https://doi.org/10.1109/ACCESS.2019.2902501

Jüttner, U., & Maklan, S. (2011). Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Management: An International Journal, 16*(4), 246-259. https://doi.org/10.1108/13598541111139062

Kashmanian, R. M. (2017). Building greater transparency in supply chains to advance sustainability. *Environmental Quality Management, 26*(3), 73-104. https://doi.org/10.1002/tqem.21495
Khot, S., & Thiagarajan, S. (2019). Resilience and sustainability of supply chain management in the Indian automobile industry. *International Journal of Data and Network Science, 3*(4), 339-348. http://dx.doi.org/10.5267/j.ijdns.2019.4.002
Kim, J.-S., & Shin, N. (2019). The impact of Blockchain technology application on supply chain partnership and performance. *Sustainability, 11*(21), 6181. https://doi.org/10.3390/su11216181
Koilo, V. (2021). Developing new business models: Logic of network value or cross-industry approach. *Problems and Perspectives in Management, 19*(2), 291-307. http://dx.doi.org/10.21511/ppm.19(2).2021.24
Kurdi, B., Alzoubi, H., Akour, I., & Alshurideh, M. (2022). The effect of blockchain and smart inventory system on supply chain performance: Empirical evidence from retail industry. *Uncertain Supply Chain Management, 10*(4), 1111-1116. http://dx.doi.org/10.5267/j.uscm.2022.9.001
Kurniasari, F., Gunardi, A., Putri, F., & Firmansyah, A. (2021). The role of financial technology to increase financial inclusion in Indonesia. *International Journal of Data and Network Science, 5*(3), 391-400. http://dx.doi.org/10.5267/j.ijdns.2021.5.004
Laroiya, C., Saxena, D., & Komalavalli, C. (2020). Applications of Blockchain technology. In S. Krishnan, V. E. Balas, E. G. Julie, Y. H. Robinson, S. Balaji, & R. Kumar (Eds.), *Handbook of research on Blockchain technology* (pp. 213-243): Academic Press.https://doi.org/10.1016/B978-0-12-819816-2.00009-5
Lashkari, B., & Musilek, P. (2021). A comprehensive review of blockchain consensus mechanisms. *IEEE Access, 9*, 43620-43652. https://doi.org/10.1109/ACCESS.2021.3065880
Lin, S.-Y., Zhang, L., Li, J., Ji, L.-l., & Sun, Y. (2022). A survey of application research based on blockchain smart contract. *Wireless Networks, 28*(2), 635-690. https://doi.org/10.1007/s11276-021-02874-x
Liu, L., Tsai, W.-T., Bhuiyan, M. Z. A., Peng, H., & Liu, M. (2022). Blockchain-enabled fraud discovery through abnormal smart contract detection on Ethereum. *Future Generation Computer Systems, 128*, 158-166. https://doi.org/10.1016/j.future.2021.08.023
Lutfi, M., Buntuang, P. C. D., Kornelius, Y., Erdiyansyah, & Hasanuddin, B. (2020). The impact of social distancing policy on small and medium-sized enterprises (SMEs) in Indonesia. *Problems and Perspectives in Management, 18*(3), 492-503. http://dx.doi.org/10.21511/ppm.18(3).2020.40
Mann, S., Potdar, V., Gajavilli, R. S., & Chandan, A. (2018). *Blockchain Technology for Supply Chain Traceability, Transparency and Data Provenance*. Paper presented at the Proceedings of the 2018 International Conference on Blockchain Technology and Application, Xi'an, China. https://doi.org/10.1145/3301403.330140810.1145/3301403.3301408
McGhin, T., Choo, K.-K. R., Liu, C. Z., & He, D. (2019). Blockchain in healthcare applications: Research challenges and opportunities. *Journal of Network and Computer Applications, 135*, 62-75. https://doi.org/10.1016/j.jnca.2019.02.027
Monrat, A. A., Schelén, O., & Andersson, K. (2019). A Survey of Blockchain From the Perspectives of Applications, Challenges, and Opportunities. *IEEE Access, 7*, 117134-117151. https://doi.org/10.1109/ACCESS.2019.2936094
Montecchi, M., Plangger, K., & West, D. C. (2021). Supply chain transparency: A bibliometric review and research agenda. *International Journal of Production Economics, 238*, 108152. https://doi.org/10.1016/j.ijpe.2021.108152
Mubarik, M. S., Bontis, N., Mubarik, M., & Mahmood, T. (2022). Intellectual capital and supply chain resilience. *Journal of Intellectual Capital, 23*(3), 713-738. https://doi.org/10.1108/JIC-06-2020-0206
Muna, N., Yasa, N., Ekawati, N., & Wibawa, I. (2022). A dynamic capability theory perspective: borderless media breakthrough to enhance SMEs performance. *International Journal of Data and Network Science, 6*(2), 363-374. http://dx.doi.org/10.5267/j.ijdns.2022.1.001
Musamih, A., Salah, K., Jayaraman, R., Arshad, J., Debe, M., Al-Hammadi, Y., & Ellahham, S. (2021). A Blockchain-Based Approach for Drug Traceability in Healthcare Supply Chain. *IEEE Access, 9*, 9728-9743. https://doi.org/10.1109/ACCESS.2021.3049920
Nguyen, D. C., Pathirana, P. N., Ding, M., & Seneviratne, A. (2020). *Blockchain and Edge Computing for Decentralized EMRs Sharing in Federated Healthcare.* Paper presented at the GLOBECOM 2020 - 2020 IEEE Global Communications Conference. https://doi.org/10.1109/GLOBECOM42002.2020.9347951
Nofer, M., Gomber, P., Hinz, O., & Schiereck, D. (2017). Blockchain. *Business & Information Systems Engineering, 59*(3), 183-187. https://doi.org/10.1007/s12599-017-0467-3
Ozdemir, D., Sharma, M., Dhir, A., & Daim, T. (2022). Supply chain resilience during the COVID-19 pandemic. *Technology in Society, 68*, 101847. https://doi.org/10.1016/j.techsoc.2021.101847
Parast, M. M. (2022). Toward a contingency perspective of organizational and supply chain resilience. *International Journal of Production Economics, 250*, 108667. https://doi.org/10.1016/j.ijpe.2022.108667
Perkumiene, D., Osamede, A., Andriukaitienė, R., & Beriozovas, O. (2021). The impact of COVID-19 on the transportation and logistics industry. *Problems and Perspectives in Management, 19*(4), 458-469. http://dx.doi.org/10.21511/ppm.19(4).2021.37
Pettit, T. J., Croxton, K. L., & Fiksel, J. (2019). The evolution of resilience in supply chain management: A retrospective on ensuring supply chain resilience. *Journal of Business Logistics, 40*(1), 56-65. https://doi.org/10.1111/jbl.12202
Queiroz, M. M., Telles, R., & Bonilla, S. H. (2020). Blockchain and supply chain management integration: a systematic review of the literature. *Supply Chain Management: An International Journal, 25*(2), 241-254. https://doi.org/10.1108/SCM-03-2018-0143
Raja Santhi, A., & Muthuswamy, P. (2022). Influence of Blockchain Technology in Manufacturing Supply Chain and Logistics. *Logistics, 6*(1), 1-22. https://doi.org/10.3390/logistics6010015

Rejeb, A., Keogh, J. G., & Treiblmaier, H. (2019). Leveraging the internet of things and blockchain technology in supply chain management. *Future Internet, 11*(7), 161. https://doi.org/10.3390/fi11070161

Saha, E., Rathore, P., Parida, R., & Rana, N. P. (2022). The interplay of emerging technologies in pharmaceutical supply chain performance: An empirical investigation for the rise of Pharma 4.0. *Technological Forecasting and Social Change, 181*, 121768. https://doi.org/10.1016/j.techfore.2022.121768

Salah, K., Nizamuddin, N., Jayaraman, R., & Omar, M. (2019). Blockchain-based soybean traceability in agricultural supply chain. *IEEE Access, 7*, 73295-73305. https://doi.org/10.1109/ACCESS.2019.2918000

Saurabh, S., & Dey, K. (2021). Blockchain technology adoption, architecture, and sustainable agri-food supply chains. *Journal of Cleaner Production, 284*, 124731. https://doi.org/10.1016/j.jclepro.2020.124731

Shamsi, K., Li, M., Plaks, K., Fazzari, S., Pan, D. Z., & Jin, Y. (2019). IP Protection and Supply Chain Security through Logic Obfuscation: A Systematic Overview. *ACM Trans. Des. Autom. Electron. Syst., 24*(6), 1-36. https://doi.org/10.1145/3342099

Sodhi, M. S., & Tang, C. S. (2019). Research opportunities in supply chain transparency. *Production and Operations Management, 28*(12), 2946-2959. https://doi.org/10.1111/poms.13115

Song, J. M., Sung, J., & Park, T. (2019). Applications of Blockchain to Improve Supply Chain Traceability. *Procedia Computer Science, 162*, 119-122. https://doi.org/10.1016/j.procs.2019.11.266

Spieske, A., & Birkel, H. (2021). Improving supply chain resilience through industry 4.0: A systematic literature review under the impressions of the COVID-19 pandemic. *Computers & Industrial Engineering., 158*, 107452. https://doi.org/10.1016%2Fj.cie.2021.107452

Sunny, J., Undralla, N., & Madhusudanan Pillai, V. (2020). Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers & Industrial Engineering., 150*, 106895. https://doi.org/10.1016/j.cie.2020.106895

Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: definition, review and theoretical foundations for further study. *International Journal of Production Research, 53*(18), 5592-5623. https://doi.org/10.1080/00207543.2015.1037934

Uddin, M. (2021). Blockchain Medledger: Hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry. *International Journal of Pharmaceutics, 597*, 120235. https://doi.org/10.1016/j.ijpharm.2021.120235

Wallbach, S., Lehner, R., Roethke, K., Elber, R., & Benlian, A. (2020). *Trust-building effects of blockchain features – An empirical analysis of immutability, traceability and anonymity.* Paper presented at the ECIS 2020.

Wang, S., Ouyang, L., Yuan, Y., Ni, X., Han, X., & Wang, F. Y. (2019). Blockchain-enabled smart contracts: Architecture, applications, and future trends. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 49*(11), 2266-2277. https://doi.org/10.1109/TSMC.2019.2895123

Wang, Z., Jin, H., Dai, W., Choo, K.-K. R., & Zou, D. (2020). Ethereum smart contract security research: survey and future research opportunities. *Frontiers of Computer Science, 15*(2), 152802. https://doi.org/10.1007/s11704-020-9284-9

Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X., & Xiao, Q. (2020). Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Automation in Construction, 111*, 103063. https://doi.org/10.1016/j.autcon.2019.103063

Wong, C. W. Y., Lirn, T.-C., Yang, C.-C., & Shang, K.-C. (2020). Supply chain and external conditions under which supply chain resilience pays: An organizational information processing theorization. *International Journal of Production Economics, 226*, 107610. https://doi.org/10.1016/j.ijpe.2019.107610

Wüst, K., & Gervais, A. (2018). *Do you Need a Blockchain?* Paper presented at the 2018 Crypto Valley Conference on Blockchain Technology (CVCBT). https://doi.org/10.1109/CVCBT.2018.00011

Yiu, N. C. K. (2021). Decentralizing supply chain anti-counterfeiting and traceability systems using blockchain technology. *Future Internet, 13*(4), 84. https://doi.org/10.3390/fi13040084

Zahed Benisi, N., Aminian, M., & Javadi, B. (2020). Blockchain-based decentralized storage networks: A survey. *Journal of Network and Computer Applications, 162*, 102656. https://doi.org/10.1016/j.jnca.2020.102656

Zelbst, P. J., Green, K. W., Sower, V. E., & Bond, P. L. (2020). The impact of RFID, IIoT, and Blockchain technologies on supply chain transparency. *Journal of Manufacturing Technology Management, 31*(3), 441-457. https://doi.org/10.1108/JMTM-03-2019-0118

Zhu, P., Hu, J., Zhang, Y., & Li, X. (2020). A Blockchain based solution for medication anti-counterfeiting and traceability. *IEEE Access, 8*, 184256-184272. https://doi.org/10.1109/ACCESS.2020.3029196